An examination of the geographical distribution of the races gives little information. For example, the two collections from Tenterfield are similar, whilst the two from Wamberal are unlike. The one from southern Queensland is dissimilar to the one from the North Coast of New South Wales.

TABLE 3.

Reactions of Isolates of C. lindemuthianum *on Bean Varieties as well as the Reactions Previously Reported.*

Varietal Accession Number.	Reactions of Races.											
	Alpha.	Beta.	Gamma.	N.Z.	Aust. *A*.	Aust. *B*.	Aust. *C*.	Aust. *D*.	Aust. *E*.	Aust. *F*.	Aust. *G*.	Aust. *H*.
B1	S	S	S	S	S	S	S	S	R	S	S	R
B2	R	S	S	S	S	R	R	R	R	R	R	R
B3	S	S	S	S	S	S	R	S	S	S	S	S
B4	S	R	R	R	R	R	R	R	R	R	R	R
B5	S	S	S	S	S							
B6	S	S	S	S	S							
B7	R	S	S	S	S	S	S	S	S	S	S	S
B8	S	R	R	R	R	R	R	R	R	R	R	R
B9	S	R	R	R	R	S	R	R	R	R	R	R
B10	R	R	S	S	R	S	R	S	R	R	R	R
B11	S	S	S	S	S							
B12	S	R	R	R	R	R	R	R	R	R	R	R
B13	R	R	S	S	R	R	R	R	R	R	R	R
B14	R	S	S	S	R	S	R	S	R	S	R	S
B15	S	S	S	S	S	S	S	S	S	S	S	S
B16				R	R	R	R	R	R	R	R	R

A study of their distribution in time is also of little value. From the Gosford area three races were found in a particular year, whereas some stability is shown in other instances.

For this information a much more extensive survey of the physiologic races in regard to both time and space would be necessary.

TABLE 4.

The Identity of the Races under Consideration Shown in Simplified Form.

Race Designation.	Reactions Shown on Differential Varieties.					
	B1.	B2.	B3.	B9.	B10.	B14.
Alpha	S	R	S	S	R	R
Beta	S	S	S	R	R	S
Gamma	S	S	S	R	S	S
Aust. *A*	S	S	S	R	R	R
Aust. *B*	S	R	S	S	S	S
Aust. *C*	S	R	R	R	R	R
Aust. *D*	S	R	S	R	S	S
Aust. *E*	R	R	S	R	R	R
Aust. *F*	S	R	S	R	R	S
Aust. *G*	S	R	S	R	R	R
Aust. *H*	R	R	S	R	R	S

It will be seen in Table 3 that a number of the varieties do not serve to differentiate the Aust. races, showing either susceptibility or resistance throughout the tests. Thus B7 and B15 are susceptible, and B4, B8, B12, B13, and B16 are resistant throughout. This makes it possible to simplify the race determinations as shown in Table 4, in which the comparable alpha, beta, and gamma results are included. The race designated Aust. *A* in the first set of studies is also set down.

Tests of Varietal Behaviour to Attack.

Using 14 of the same set of isolates, numerous varieties of beans were subjected to test. One of the original isolates (Acc. No. 768) was lost before the tests had been completed.

An extreme range of diversity to attack was shown. The varieties fell into one or other of 42 classes. At one end of the scale the class of varieties showed resistance to all

TABLE 5.

The Classes (or Races) Determined when 132 Varieties were Tested with 14 Isolates of C. lindemuthianum.

Acc. No.	Variety.	Reactions Shown.													
		767	985	986	987	988	989	990	1026	1028	1034	1035	1036	1038	1043
V2	Russia.	R	R	R	R	R	R	R	R	R	R	R	R	R	R
V3	Roger's Stringless Green Pod Refugee.	R	R	R	R	R	R	R	R	R	R	S	S	S	R
V10	Stringless Green Pod Refugee.	S	S	R	S	S	S	S	S	S	S	S	S	S	S
V11	Pencil Pod Black Wax.	R	S	S	R	S	S	S	S	R	R	S	S	S	S
V12	Florida Belle.	S	S	R	S	S	R	S	S	R	S	S	R	S	S
V14	Blue Lake Hybrid 65.	R	R	R	R	S	S	S	R	R	R	R	R	R	R
V20	Brown Beauty (A.T.P.).	S	R	R	R	R	R	R	R	R	R	R	R	S	S
V25	Doppelite.	R	R	R	S	S	S	S	S	S	R	R	R	R	R
V28	Early Pale Dun.	S	S	S	S	S	S	S	S	S	S	S	S	S	S
V32	Tweed Wonder.	R	R	R	R	R	R	R	R	R	R	R	R	S	S
V46	U.S. Refugee No. 5	R	S	S	R	S	R	R	R	R	R	R	R	S	S
V52	Staley's Surprise.	S	S	R	R	S	R	R	S	S	R	S	R	R	S
V65	Top Crop.	R	S	S	R	R	R	S	R	R	S	S	S	S	S
V67	Unrivalled Wax.	R	R	S	R	S	S	S	S	S	R	S	S	S	S
V68	H49.	S	S	R	R	R	R	R	S	R	R	R	R	S	S
S9	Idaho H7696.	R	R	R	R	R	R	R	R	R	R	R	R	R	S
S10	Standard Pink.	R	R	R	R	R	S	S	S	R	R	R	R	S	R
S48	Red Kidney H6454	R	R	R	R	S	R	R	R	R	R	R	R	S	S
S51	Pearl Sugar.	R	S	S	S	S	S	S	S	S	S	S	S	S	S
S70	The Wonder.	S	R	R	R	S	S	R	S	S	S	S	S	S	S
S90	Florida Belle (Asgrow's).	S	R	R	R	R	R	R	R	S	S	S	S	S	S
B1	Red Cranberry (Low's Champion).	S	S	R	S	R	S	S	S	S	S	R	S	S	S
B3	Black Valentine.	R	S	S	S	S	S	S	S	S	S	S	S	R	S
B10	Well's Red Kidney.	R	S	R	R	R	R	R	R	R	R	R	R	R	R
B14	Yellow Eye (Improved).	R	S	R	S	R	R	R	R	S	R	S	S	R	R
B30	Kentucky Wonder.	R	R	R	S	R	R	R	R	R	R	R	R	R	R
B32	Wellington Wonder.	S	S	R	R	R	R	R	R	R	R	R	R	S	S
B38	Prolific.	R	R	R	R	S	S	R	S	S	R	R	R	R	R
B40	Pacer.	R	S	R	R	S	S	S	R	S	S	S	S	S	S
B41	Burbank.	R	R	R	R	R	R	S	R	S	S	R	R	R	R
B43	Yellow Eye.	R	S	R	S	R	R	S	R	R	S	S	R	R	R
B45	Norwegian.	S	S	S	S	S	S	S	S	S	S	R	R	S	S
B46	Habilla.	R	S	S	R	R	R	R	R	R	R	R	R	S	R
B54	Poroto enana.	R	R	S	S	S	S	S	S	S	S	R	S	R	R
B55	Poroto C.P.I. 11443.	R	S	R	R	S	S	R	S	R	S	S	S	S	S
B60	Supergreen.	R	S	R	S	R	S	R	S	R	R	R	R	R	R
B63	Native Bean H7789.	R	R	S	S	S	S	R	S	S	S	S	R	R	R
B67	Florida Belle.	R	S	R	S	R	R	R	R	R	S	R	R	S	S
B73	Scott's Bluff Pinto.	R	S	S	S	S	R	S	S	S	S	S	R	R	R
B74	Startler Wax.	R	S	S	R	R	S	S	S	S	S	R	S	R	S
B78	The Wonder.	R	S	S	S	R	R	S	R	R	S	R	R	S	S
B81	Standard Pink.	R	R	R	S	S	S	R	R	R	S	R	R	R	R

the isolates; at the other, susceptibility to all was shown. In between these two classes were those in which 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, or 13 of the isolates gave rise to susceptible reactions. In each of these cases resistance was, of course, shown to the remaining isolates. Furthermore, there were various groupings within these classes. For example, there were six different groupings within the "3 susceptible" class, five groupings in each of the "4 susceptible", "5 susceptible", and "10 susceptible" classes, four groupings in the "9 susceptible" class, and so on. It is clear that when large numbers of host plants are used as differentials, an extreme range of diversity is exhibited. In this case no one of the 14 isolates examined was the same when subjected to this test.

TABLE 6.

List of Varieties Tested where More than One Fell within the Several Classes.

Class 1.—Resistant to All the Isolates.

V2 Russia, V4 Rainy River, V5 Klein Weisse, V6 Pink, V9 Great Northern, V13 Blue Lake, V15 Blue Lake Stringless Pole, V16 Boston Marrow, V18 Burbank, V21 Californian Small White, V22 Cannellini, V23 Case Knife, V24 Case Knife Climbing White Dutch, V26 Hamburger Market, V27 Early White, V29 Emperor William, V31 Frigole Nigros, V34 Java, V35 Michigan Robust, V36 Michelite, V37 Robust, V38 Norida, V40 Navy, Canadian Type, V41 Navy, Ottawa, V42 Northern Star, V44 Purple Pod, V49 Red Mexican U. I. 3, V50 Red Mexican U. I. 34, V53 Zucker Perl, V58 Red Valentine, V61 Roumanian White Pea, V63 Pilot, V64 Bill, V69 Corbett's Refugee, S4 Otenashi, S8 Little Navy, S31 Pinto H6781, S34 Michelite, S36 B2675, S47 Pilot, S57 Small White, S66 Shravni Ghendi, S67 Native Bean H7790, S69 Fullgreen, S71 Cromer, S100 Dwarf Haricot (Comptesse di Chambord), S118 Pilot, S122 Rice, S124 Roger's Refugee 1071, B4 Tennessee Green Pod, B8 Kentucky Wonder, B9 Scotia, B12 Michigan Robust, B13 White Imperial, B16 Epicure, B18 Wiggin's Prolific, B25 U.S. No. 3, B27 Harter's 643, B28 Harter's 650, B29 Harter's 765, B31 Harter's 814, B33 Blue Navy, B35 Cecic's Epicure, B37 Kentucky Wonder, W.A., B44 C.P.I. 11272, B48 Alabama No. 1, B49 Feijao, B51 Poroto C.P.I. 11439, B52 Poroto C.P.I. 11440, B53 Poroto topero, B57 Poroto criollo, B58 Poroto cuarenton, B59 Poroto arroz chilero, B61 Ideal Market, B68 Long White Marrow, B69 St. Fiacre, B70 Resistant Kentucky Wonder, W.A., B75 Roger's Refugee 1071, B76 Medal, B77 Great Northern, B79 Fullgreen No. 1, B80 Fullgreen No. 2, B82 Roumanian White, B83 Early Pink, B84 Russia, B85 Pilot, B88 Westralia, Scarlet Runner, also ten of the original selections from which Westralia was isolated, *Dolichos Lablab* (six isolates), two of them giving "2" reactions.

Class 2.—Susceptible to All the Isolates.

V17 Burpee's Dwarf Stringless Green Pod, V28 Early Pale Dun, V54 Surecrop Wax U.S.A., V60 Low's Champion, S53 Granda, S85 Dwarf Pencil Pod Wax, S95 Pencil Pod Wax (Ferry Morse), B7 Red Kidney, B19 Hawkesbury Wonder, B20 Wardwell Kidney Wax, B21 Lazy Wife, B22 Stringless Black Valentine, B24 Clarendon Wonder, B26 Harter's 181 (Bountiful), B34 Stringless Green Pod French Bean, B36 (Clarendon Wonder × Wellington Wonder), B47 Frijol pico de oro, B50 Frijol guarzo rayado, B56 Feijao rayado, B64 Granda, B65 Tendergreen, B71 Staley's Surprise, B72 Red Valentine.

Class 3.

Isolates.

767	985	986	987	988	989	990	1026	1028	1034	1035	1036	1038	1043
R	R	R	S	R	R	R	R	R	R	R	R	R	R

V33 Hidatsa Red, B30 Harter's 780.

Class 4.

R	R	R	R	R	R	R	R	R	R	R	R	S	S

V32 Tweed Wonder, V39 Negro Long Pod, V45 Idaho Refugee, V56 The Wonder, V62 Medal, S17 The Prince, S59 Tweed Wonder.

Class 5.

R	S	S	S	S	S	S	S	S	S	S	S	R	S

B3 Black Valentine, B66 Black Valentine.

The various classes determined are shown in Table 5, where one variety of each is listed.

It will be noted that the variety "Florida Belle" appears in three and "Standard Pink" in two of the categories. In each case the seed came from different sources, but the variety appeared to be the same. Differences in resistance within a given variety are clearly shown.

Where more than one variety fell within a class they are set out in Table 6.

TABLE 7.

Reactions Shown by Nine Bean Varieties when Inoculated with Fourteen Different Isolates of C. lindemuthianum.

Accession Numbers of Isolates.	Race Designation.	Reactions Shown by Varieties.								
		Tweed Wonder.	Wellington Wonder.	Kentucky Wonder.	Black Valentine.	Brown Beauty (A.T.P.).	Staley's Surprise.	Startler Wax.	Hawkesbury Wonder.	Epicure.
767	Aust. 1	R	S	R	R	S	S	R	S	R
985	Aust. 2	R	S	R	S	R	S	S	S	R
986, 989, 990, 1034, 1036 ..	Aust. 3	R	R	R	S	R	R	S	S	R
987	Aust. 4	R	R	S	S	R	R	R	S	R
988, 1035 ..	Aust. 5	R	R	R	S	R	S	R	S	R
1026, 1028 ..	Aust. 6	R	R	R	S	R	S	S	S	R
1038	Aust. 7	S	S	R	R	S	R	R	S	R
1043	Aust. 8	S	S	R	S	S	S	S	S	R

It is seen that judging by these tests there is a wealth of resistant material available. Many of the varieties exhibit the climbing habit, but a number of the dwarf type are included. No association of resistance with any particular seed character could be found. Nothing regarding the real nature of host resistance is known.

TABLE 8.

A Comparison of the Determinations Made by Using the Two Different Sets of Varieties.

Race Designation.	
Second Test.	First Test.
Aust. 1	Aust. *B*
2	*D*
3	*E, F, G*
4	*F*
5	*E, H*
6	*F, G*
7	*C*
8	*G*
1	*B*
7	*C*
2	*D*
3, 5	*E*
3, 4, 6	*F*
3, 6, 8	*G*
5	*H*

In order to relate these results to those in which the smaller set of differentials was used (p. 75), the determinations have been simplified by making an empirical choice from the 132 varieties of a small group of nine of the better known varieties. The varieties Hawkesbury Wonder (susceptible throughout) and Epicure (resistant throughout) do not actually serve as differentials, but are included as useful commercial varieties, as well as types of their respective behaviours.

On this basis the determinations are as in Table 7.

On this basis eight races are sorted out. But they do not correspond with the eight previously determined with the other set of differentials. One of them (Aust. 3) comprises three of the former races (Aust. *E*, *F*, and *G*), and two of them (Aust. 6 and 7) each comprise two of the former races (Aust. *E* and *H*, and Aust. *F* and *G* respectively). A comparison is shown in Table 8.

An examination of the distribution of types on a space and/or time basis again gives no satisfying information.

Discussion.

A knowledge of the nature of the causal organism is essential to success in any attempt to control the disease. These studies were designed to throw some light on the host-parasite relationships that exist in the disease known as anthracnose of beans.

The first set of studies carried out between 1925 and 1928 revealed the presence in Australia of two physiologic races. One of them agreed with that recorded in U.S.A. as the beta race, and was present in 11 of the 12 isolates examined. The remaining one was different in its behaviour on one of the bean differential varieties, and has been styled Aust. *A*. This designation will not conflict with others in the literature where symbols such as Roman numerals are commonly used. From the small number of isolates no information of value could be got in regard to the distribution of the two races in time and space.

In the second set of studies, carried out between 1944 and 1952, 14 isolates were used in race determinations similar to those done previously. One came from Queensland, the rest from New South Wales. The presence was revealed of seven physiologic races, all different from the two found in the earlier work. They have been styled Aust. *B* to Aust. *H*.

During the interval between the two sets of studies there has been no appreciable change in the commercial varieties under cultivation. In other diseases, like the rusts of cereals, a marked change in the popularity of varieties because of their differential resistance has led to a marked change in the physiologic races present: a screening of the races has occurred, leading to the change in the rust flora as determined in the survey (Waterhouse, 1952). In this work on beans the change in the races determined cannot be explained in this way. The pathogen is seed-borne, and it is possible that the "new" races were introduced in seed brought from overseas. No sexual stage of the anthracnose fungus has been demonstrated, and so hybridization is ruled out. Hyphal fusions of differing mycelia could produce "new" races, but this happening has not been proved. Mutation of fungi has been demonstrated many times, and may be the explanation of the present happenings. What is important is that changes in a parasite as determined by its relationship with the host are constantly occurring. Where comparative studies are to be made, it is quite inadequate for morphological features to be regarded as a criterion of identity. Continuous checking of the physiological behaviour is necessary.

In such work the invariability of variation in the host is also of fundamental importance. Retention of genetic purity of the differential varieties used as hosts is essential. And if comparisons of results obtained by different workers are to be made, not only must the environmental conditions under which the tests are carried out be uniform, but the same genetically pure host material must be used as well.

The work reported herein shows clearly the need for these precautions. In a crop like beans, which are so widely grown, and in which seed is often sent from one country to another, confusion of names is not uncommon. In a new locality a local name may be substituted for the former name. A particular selection from imported material which is multiplied and established because of its particular characteristics may still carry the former name, whereas it may be of a different constitution from that of the original variety.

An example may be given. It was reported recently that Westralia beans were attacked by rust in New South Wales. Close examination showed that the "Westralia" crop which was rusted was not the real rust-resistant Westralia, although it appeared to be the same (Cass-Smith et al., 1954). Westralia itself is stated to have its origin in a natural cross between Golden Harvest and a brown-seeded Kentucky Wonder (Cass-Smith et al., 1951). It was estimated that natural crossing occurred to the extent of 2%.

Our work has shown clearly the occurrence of natural crossing under Sydney metropolitan conditions, although only very limited observations have been possible. In 1954, from a pedigree row of Westralia, pods harvested from two plants yielded respectively mottled purple and light brown seeds. Six plants were produced; all were climbers, but they show clear differences in habit of growth, shape of leaf, and colour of flower. Further pedigree work with them is in progress, and may yield further information on the happening. It was known that several other varieties and crossbreds were growing some 10 to 12 feet away from the Westralia row.

In another instance, in 1953, a plant resembling Westralia was found in a row of this variety, also grown from pedigree seed. It produced rather flat streaked seeds—brownish-black streaks on a dun background—instead of the usual kidney-shaped white seeds of Westralia. Several of these streaked seeds were sown. They developed into strongly growing climbers which showed marked variation in flower colour, from white through pink to dark pink. The pods were long, but some were round, others flat in cross-section. The seed varied in shape and size as well as in colour; some were brown streaked with black, others brown, and two showed brown streaks on a cream background.

In this case it was known that the variety called "Tiger" was growing in close proximity to the Westralia row. It is a climber with dark pink flowers and flat pods bearing seeds which have brownish-black streaks on a dun background. It seems probable that in this case a natural cross between these two varieties had occurred. Numerous attempts have been made to cross these two by hand, but without success.

In areas where seed is produced on a commercial scale and where only one variety is under cultivation, the chances of natural crossing are greatly lessened. But in plant breeders' plots, where many varieties are grown in close proximity, it seems likely that the phenomenon occurs more frequently than is generally supposed.

Variations that are due to mutation must not be ruled out. A number of cases in our work has been noted in which chimaeric conditions affecting chlorophyll development have been present, but none has been shown to be heritable.

Selection of the varieties that are to be used in the host-parasite relationship studies is made on an empirical basis. It is not yet known what constitutes resistance to attack. But because of their genic make-up, some varieties show this character when tested with a wide series of isolates of the pathogen, whereas others are susceptible throughout the tests. Others again show differences in the reactions, and hence may be useful in classifying variations in the behaviour of different isolates. Because of differences in varieties under cultivation and differences in environmental conditions, it may be expected that with the passage of time there will be differences in the physiologic races present in different areas. Hence it is likely that the set of varieties selected as differentials for one country may not have the same usefulness elsewhere. In the cereal rust investigations it has been clearly shown that local conditions will often make it imperative to modify the normally-accepted set of differentials (Waterhouse, 1952).

This has recently been found in studies of bean rust in Australia (Waterhouse, 1954). The race of rust which is now so damaging to dwarf beans is not differentiated on the normally-accepted set of differentials, but is separated clearly when a local variety is added to the set.

Not only does a modified set of differentials give a more accurate picture of the host-parasite relationship that exists, but it generally gives far more assistance to the worker who is breeding for disease resistance.

In this work the normally-accepted set of six bean differentials has been used and eight physiologic races sorted out; they are styled Aust. *A* to Aust. *H*. They differ from the races recorded in U.S.A. as the alpha, beta, and gamma races. Using a totally different set of seven varieties, chosen as a result of testing more than 130 varieties for their reactions, it happens that again eight races have been determined: they are styled Aust. 1 to Aust. 8. Whilst the results of the two sets of determinations show agreement in the case of three of the isolates, the others do not. Because of the relative ease in maintaining stocks of the second set of differentials in Australia, it is likely that this set will be found to be the more useful here. It may well be that further investigations will lead to modifications in this choice of varieties.

The simplified set of differentials just referred to came from the extended tests of varieties which showed that when the number of varieties tested is large, a very large number of variants of the pathogen may be distinguished. The tests show that there are numerous bean varieties available which were resistant to all the isolates used. A wider selection of isolates may well reduce this list of resistant varieties.

In recent communications (personal communications, 1954 and 1955), Mr. W. P. Cass-Smith, Plant Pathologist of the W.A. Department of Agriculture, states that a new situation has arisen in that State. Anthracnose of beans has recently shown up on Westralia, which on account of its strong rust resistance is now being grown late in the season. The temperatures are then relatively low, and anthracnose has been able to attack these crops of Westralia. In our tests the variety itself, as well as ten families from which it was ultimately selected and named, were quite resistant to all the isolates examined. It seems clear that a different race—or races—of *C. lindemuthianum* is present in Western Australia.

Because of its resistance to rust and its resistance to all the isolates of *C. lindemuthianum* tested, Westralia was selected as a parent in crosses and back-crosses with dwarf beans like Hawkesbury Wonder designed to combine the dual resistance with the commercially desirable characters of the dwarf type. This work is well under way, but the W.A. occurrence of anthracnose may mean that the Westralia resistance will be inadequate. If the anthracnose from Western Australia reaches New South Wales, this seems certain. Several other varieties, like Feijao, Little Navy, Resistant W.A. Kentucky Wonder, Harter's 814, and Scarlet Runner have also been used as parents having the dual resistance, but nothing is known about the basis of their resistance as compared with that of Westralia. Many other varieties also will be seen to combine the rust and anthracnose resistance.

From 200 pollinations of Hawkesbury Wonder with Westralia made between 1951 and 1954, only 10 have been successful. Very generally there is some development of the pod, but it soon stops growing and drops off. This is illustrated in Plate iii, in which the three basal flowers of the raceme were pollinated with Westralia, yielding tiny sterile pods in contrast to the normally-developed pods which were from selfed flowers. In the successful cases the pods developed were small and contained an average of only two seeds each. In one instance the crossed pod yielded seven seeds, but when they were grown, only four were crosses, the other three being straightforward Hawkesbury Wonder plants.

The F1 plants showed very poor development and produced an average of only 15 seeds each, thus curtailing very much the F2 examination; always some plants have been very feeble and have soon died. The segregating plants show marked sterility in seed-setting in some individuals, taking the form of tiny sterile seeds interspersed with normal seeds in a pod. Similar sterility effects have been found in the two crosses, Hawkesbury Wonder × W.A. Resistant Kentucky Wonder, and Hawkesbury Wonder × Kentucky Wonder Hybrid. The W.A. Resistant Kentucky Wonder is the supposed parent of Westralia which gave the latter its resistance. Counts involving 118 pods and 850 seeds gave a 20% sterility occurrence. There is a clear need for cytogenetical studies of these happenings.

The variety Scarlet Runner (*Phaseolus coccineus* L.) has been even more difficult to cross. It is still too soon to evaluate the results.

The late Mr. R. D. Wilson recorded (Wilson, 1950) striking differences between what he called Strain 1, to which the varieties Wellington Wonder and Tweed Wonder were resistant, and Strain 2, to which they were susceptible. The present work fully substantiates this finding. It is clear that on the basis of the reactions given by additional varieties the two strains can be further split up.

An endeavour has been made to link up with the results reported by Egerton and Moreland (1916), Leach (1923), Rands and Brotherton (1925), Müller (1926), Schreiber (1932), Müller (1941), Reid (1943 and 1945), and Hubbeling (1946). In places some of the varieties used in the current work are included in the results reported, but there are so many differences in the varieties used that no valid comparisons can be made.

The amount of variation in *C. lindemuthianum* which has been so clearly established in Australia may well be further extended if further local studies are made. It is a happening that must always be taken fully into account in any programme designed to yield anthracnose-resistant varieties of beans.

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EXPLANATION OF PLATE III.

A and B: Resistant and susceptible varieties respectively, inoculated with *C. lindemuthianum*. $\times \frac{1}{4}$.

C: A raceme of a growing plant of Hawkesbury Wonder three weeks after pollination. The three basal flowers were pollinated with Westralia, and show the typical stunted pod development in contrast to the normal development of the other pods on the raceme from flowers which were self-pollinated. $\times \frac{1}{3}$.

THE PETROLOGY OF THE NORTHERN PART OF THE WYANGALA BATHYLITH.

By N. C. Stevens.

(Plate iv; two Text-figures.)

[Read 27th April, 1955.]

Synopsis.

Gneissic and massive granites of the Wyangala bathylith, central New South Wales, are intrusive into Ordovician and Silurian sediments and volcanic rocks as well as sporadically distributed diorite and amphibolite. Thermal metamorphism has affected chiefly the Ordovician tuffs and calcareous sediments, producing amphibole-plagioclase hornfelses. Chemical data suggest that the Cowra Granodiorite may belong to the Wyangala bathylith whereas the Pine Mount Granodiorite has less marked affinities with the other granitic rocks. The geological setting is not in keeping with large-scale granitization *in situ*, but a porphyritic gneissic phase is thought to have originated by granitization of sediments at depth. Finally, the age of the Wyangala bathylith and allied masses in S.E. New South Wales is discussed.

Introduction.

Between Cowra and Gunning in central and southern New South Wales a considerable area is occupied by a great granitic mass (termed in this paper the Wyangala bathylith), of which only the northern part, between Cowra and Frogmore, has been mapped and examined. The mapping has been of the nature of a detailed reconnaissance, and the following description of some of the interesting features of the bathylith will serve as an introduction to more detailed studies to be carried out in the future.

Along the 149th meridian the granites extend from Garland to Taylor's Flat (Plate iv), a distance of over 40 miles, but tongues may be traced east into the Abercrombie River region, so that the mass examined is linked with another elongated area of similar granites, which may be followed for 50 miles south of Bigga to Gunning and beyond. Further south are the Murrumbidgee and Kosciusko bathyliths, made up of strikingly similar rocks with similar chemical and mineralogical composition, structural characteristics and relations with the invaded rocks. Browne (1929, 1950) has assigned a late Silurian age to these concordant intrusions and has correlated them with similar granitic rocks as far apart as Wyalong and Hillgrove.

Prior to the present investigation, gneissic granites had been noted from Gunning and Wheeo, near Crookwell (Browne, 1929), but their extension north of these places was unknown. Harper (1929) had mapped a lenticular area of strongly gneissic granite at Wyangala Dam spillway, but did not realize that the surrounding granite had a distinct foliation. Reports on the Frogmore wolfram mines (Harper, 1919; Mulholland, 1950) pay little attention to the granites.

The Palaeozoic stratified rocks range from Middle Ordovician to Upper Devonian and include the previously described Walli Andesite (Stevens, 1952*a*) and the southern continuation of the Upper Devonian formation found in the Conimbla Mountains west of Cowra (Stevens, 1951). New formation names used on the map (Plate iv) are the Kenyu Formation and the Illunie Rhyolite. The Kenyu Formation, of probable Ordovician age, is exposed along the western margin of the Wyangala bathylith and consists of siltstones, slates, tuffs, andesites and occasional limestone lenses. The Illunie Rhyolite, which appears to overlie the Silurian sediments and porphyries east of Koorawatha, is chiefly made up of acid lavas and tuffs with indistinct flow banding and stratification. It is unconformably overlain by the Upper Devonian rocks, with a difference in strike of about 30°.

ALTERATION OF THE COUNTRY ROCKS.

The Wyangala bathylith is intrusive into Ordovician rocks except in the south-west part near Gunnary, where the country rocks are Silurian porphyries, tuffs and breccias. On the eastern side of the area examined the Ordovician rocks are pelites and psammites, but on the western side and at the northern and southern margins of the main granite mass near Woodstock and Kenyu the country rocks are andesites, tuffs and siltstones.

The irregular distribution of contact metamorphosed rocks is related to the presence of tuffs, breccias and calcareous sediments, which were more susceptible to metamorphism than the pelitic and psammitic rocks.

Pelitic rocks show distinct thermal metamorphism on the Reid's Flat–Bigga Road and in the roof pendant near "Glen Rock" (north of Wyangala Dam). Close to the contact, cordierite is developed, giving the rocks a spotted appearance, but the interbedded sandstones have not suffered much change apart from the development of a little biotite in the matrix.

Two areas of knotted schists, one near Bolong and the other north of Frogmore, do not seem to be related to the granites which are exposed at present. The area near Bolong is a mile from the nearest exposed granite, and the area north of Frogmore, although close to the Forest Creek contact zone, trends at right angles to the contact and is outside the zone of hornfelses. Most of the rocks are silvery mica-schists, with spots or knots up to 12 mm. in diameter. Bedding is sometimes parallel to the schistosity, but contortions are often present in hand-specimens. Andalusite is sometimes preserved in the knots, but it is more commonly altered to sericitic aggregates. A bed of black slate interbedded with the schists has not been visibly affected, due possibly to the inhibitive effect of carbon, noted by Harker (1939), Turner (1948) and others.

The larger areas of hornfelses are found where the granites have invaded tuffs and calcareous sediments, e.g. at Forest Creek, between the Wyangala bathylith and the Pine Mount intrusion and near Kenyu.

The most interesting of these is the Forest Creek contact zone, between Springvale and Hovell's Creek. It is situated at the northern extremity of a belt of Ordovician slates and quartzites, bounded on either side by granites of the Wyangala bathylith. The granite-hornfels boundary is sharp but irregular (east-west); small intrusions of granite are separated from the main mass and the contact zone is intersected by dykes of acid granite and pegmatite.

The hornfelses are fine-grained greenish rocks containing amphibole, pyroxene, felspar, and, in some types, quartz or garnet. Original sedimentary bedding is sometimes evident, and one example of micro-current-bedding has been noted. A brecciated structure is visible in some of the more massive types.

The bedded hornfelses contain medium-green amphibole with varying amounts of grey pyroxene granules in darker bands which alternate with bands composed of andesine, microcline and sometimes quartz. Microcline may have been produced from original material in the sediments, but it also occurs in coarse grains associated with quartz, in which case these minerals are more likely to have been contributed by the granite.

Honey-coloured garnet (andradite-grossular) is present in some contact rocks which show relict fragmental structure. It is associated with large grains of twinned albite in certain areas and the two minerals may have been formed by the metamorphism of epidote and natrolite, occupying cavities (McLintock, 1915). Porphyroblasts of deep green amphibole are now largely replaced by granules of pale green pyroxene and are associated with biotite. The fine-grained areas consist of hornblende and granular plagioclase. Iron oxides are accessories in most of the hornfelses, and in the bedded types they are generally restricted to certain beds, notably those containing pyroxene.

The replacement of amphibole by pyroxene has been noted in several of these rocks, and it indicates two stages in metamorphism, the second stage being the more severe. The abundance of lime-bearing minerals and the presence of sedimentary structures is consistent with the view that the original rocks were calcareous sandstones, tuffs and breccias. There is a possibility that some of the hornblende may have been original, as at least two different types are present, one of which is actinolitic. That all the amphibole is not original is proved by the occurrence of a yellowish-green variety in veins through the hornfelses.

Between the Wyangala bathylith and the Pine Mount intrusion there is a zone of hornfelses up to three-quarters of a mile wide to the west of "Melrose". The rocks are mainly fine-grained amphibole-plagioclase hornfelses, some of which exhibit bedding. Less metamorphosed siltstones, tuffs and andesites are also present.

The matrix of some of the tuffs near Coota Trig. contains biotite of metamorphic origin, indicating a less calcareous composition than usual. The plagioclase phenocrysts of the andesites are penetrated by needles and clusters of actinolite, and the groundmass has been recrystallized with the formation of fresh plagioclase and actinolitic amphibole.

This zone has no doubt suffered the contact effects of granites to the north and south, but in general the Wyangala bathylith is responsible for stronger metamorphism than the Pine Mount intrusion.

East of "Melrose", amphibole-hornfelses with phyllites and schists outcrop between the two intrusions in a wedge-shaped area, widening to the north-east. Plagioclase (andesine) and green hornblende are again the dominant minerals in the hornfelses, with pale green pyroxene in minor amounts. The felspar is present in rather large grains and also constitutes much of the finely granular groundmass. Some of these hornfelses were fragmental rocks, while others may have been basic lavas. Close to the gneissic granite the rocks have been extensively sheared; normal pelitic rocks have been converted to phyllites, and lavas and tuffs have given rise to quartz-chlorite-epidote-schists. The latter have a granular quartz base with porphyroblasts of pale green chlorite in which epidote has developed, probably as a result of the intrusion of the later Pine Mount Granodiorite. Epidotization and penetration by epidote veins is more noticeable further east near Milburn Creek, where small-scale current bedding can still be seen in some of the sediments.

The only amphibole-hornfelses found east of Hovell's Crek are restricted to a small area on Mt. Darling, where they are associated with basaltic rocks and interbedded with pelites and psammopelites. Amphibole has been developed in the groundmass of the basalts and both basalts and hornfelses are penetrated by veins of zoisite, which mineral occurs in irregular areas in the basalt, representing former amygdules.

Hornfelses derived from basic tuffs occupy areas between tongues of granite at Kenyu. The metamorphic rocks are fine-grained, containing epidote and actinolitic amphibole; the former in crystals and granular aggregates and the latter in needles. The proportions of the two minerals vary greatly and some cloudy felspar is usually present.

Along the western margin of the granite and gneiss to the east of the Woodstock-Wyangala Road, fine-grained amphibole-hornfelses are interbedded with slates and sandstones within a few hundred yards of the contact. The amphibole is a pale-coloured tremolite-actinolite and is associated with a strongly pleochroic pale yellow epidote and colourless zoisite showing anomalous interference colours. The felspar is oligoclase-andesine and contains abundant minute needles of amphibole. Zoisite or epidote occurs both in the main mass of the rock and in veins traversing it. Other hornfelses near by have bands of medium-green hornblende alternating with felspathic bands. Metamorphosed tuffs containing basalt fragments and actinolite in the matrix are found to the north near Waugoola Creek, and in the same area a banded, schistose psammopelite within the contact aureole is remarkable for the occurrence of pale blue pleochroic corundum (sapphire) in irregular grains. Each grain is surrounded by a sheath of sericite and is confined to the chlorite-rich parts of the chlorite sericite bands. The corundum does not seem to be detrital, for it is restricted to the silica-poor areas.

Granite contacts are generally quite sharp, and away from the thermal aureole the sedimentary rocks are of low metamorphic grade, with no sign of regional granitization.

Silicified sediments have been intimately penetrated by porphyritic granite on Old Woman Creek, north of "Glen Rock", but the contacts suggest the sediments were in a semi-plastic condition at the time of intrusion.

Pre-Granite Diorites and Amphibolites.

Diorites and hornblende-rich rocks of medium to coarse grain-size which antedate the Wyangala bathylith granites are found at Cocomingla, Bigga, "Melrose" and in the Parish of Purfleet (between Garland and the Abercrombie River). The two largest masses are at Bigga and Cocomingla, but only the latter has been studied in detail. At most localities there is ample field evidence that the granites are intrusive into the hornblende rocks, and at "Melrose" and Cocomingla the diorites have invaded sedimentary and volcanic rocks.

At Cocomingla the basic rocks outcrop over a sub-circular area with an average diameter of about one mile. They are surrounded by granite which is coarse and massive to the west and porphyritic and gneissic to the east. On Cocomingla Creek a marginal, non-gneissic phase of the granite sends tongues and narrow veins into the basic rocks, in places forming a network. Both granite and diorite invade highly contorted and metamorphosed sediments and a single occurrence of diorite intrusive into recrystallized andesite has been observed. Dark, fine-grained xenoliths, derived from diorite and sediments, appear in the granite close to the contact.

It has been possible to map two main rock types in the complex, viz., fine- to medium-grained diorite and porphyroblastic amphibolite, although each type shows some variation. The amphibolite occupies more than half the intrusion, outcropping mainly in the central and western parts, away from the contact with the porphyritic gneiss. It grades over a short distance into more even-grained diorites, but the contact is never a sharp one, and no well-defined xenoliths of one type occur in the other.

The hornblende porphyroblasts of the amphibolite, which may be up to 9 mm. long, are euhedral and enclose minerals of the groundmass as well as sphene, pyrite and occasional biotite and apatite. Inclusions of sphene are quite irregular and the amount varies antipathetically with that of quartz. Hornblende and pyroxene are often intergrown in the groundmass, but separate crystals of each may be enclosed in larger plates of andesine, microcline or quartz. The amounts of microcline and quartz vary greatly in the amphibolites, which in many respects resemble the appinites of the Glen Tilt complex, Perthshire (Deer, 1950).

The medium and fine-grained diorites show many of the same features as the coarser types and contain the same minerals in different proportions. Many are obviously crystalloblastic, yet others have few textural features that distinguish them from normal igneous rocks. In general, the crystalloblastic types have a mottled appearance in hand-specimen, and the larger poikiloblasts of felspar give rise to "lustre mottling". Some have a greater percentage of quartz and microcline with a corresponding decrease in ferromagnesians (especially pyroxene) and plagioclase. Epidotization has proceeded to a variable degree, affecting hornblende as well as andesine in the most altered rocks.

Pegmatitic veins are found towards the margin of the intrusion on Cocomingla Creek and along the Boorowa River. Unlike the later pegmatite dykes which intersect the intrusion, the veins have irregular shape and mostly indefinite boundaries. They are more often contained in the fine- and medium-grained diorites, which exhibit a fine-grained, hornblende-rich margin against the leucocratic phases, a feature similar to that produced in hornfels at the margin of granite of the Newry complex and ascribed to a "basic front" effect (Reynolds, 1949, see Plate 7).

The chief minerals in the leucocratic segregations are oligoclase-andesine, quartz and microcline, with some hornblende usually present. Quartz appears to be replacing plagioclase, which shows micro-faulting, with irregular quartz along fractures. Hornblende is euhedral, in some places attaining a length of 30 mm. It may have a semi-radiating arrangement or be confined to melanocratic bands.

Flat-lying dykes of aplite and pegmatite which intrude the basic rocks are more uniform in thickness and shape than the leucocratic phases noted above and are